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14. ABSTRACT Lightweight, stiff mirrors can be produced by electroplating a nickel phosphide alloy over a plastic foam mandrel. 300 and 600 mm diameter flat mirrors were made using this process. Integral nickel phosphide tubes were separately formed and inserted into the mandrels before plating. The assembly was then plated and the mandrel was removed by solvent extraction. The mirror substrates were diamond turned and polished. Optical inspection is not yet complete.					
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Low Cost Very Large Diamond Turned Metal Mirror

Contract No. NNX10CB49C (SBIR 08-2 S2.04-9926) (MSFC)

Mirror Technology SBIR/STTR Workshop

June 7th to 9th, 2010

Millennium Harvest House, Boulder, Co.

**John M. Casstevens
Dallas Optical Systems, Inc.
972-564-1156**

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OUTLINE

- **CONCEPT AND GOALS**
- **MIRROR MFG. PROCESS**
- **PROGRESS TO DATE**
- **SUMMARY**

Concept and Goals

- Develop and demonstrate a process for producing a light weight, stiff mirror substrate by electroplating a NiP alloy over a plastic foam mandrel which will be removed with solvent after plating.**
- Demonstration of diamond turning as a method of producing a high quality optical surface on the electroplated NiP substrate by producing a 300 mm (12 inch) diameter flat test mirror and a 600mm (24 inch) flat mirror.**
- Optical inspection of the finished mirrors to evaluate mechanical stability and stiffness and the extent of mirror internal structure print through on the finished optical surface as a function of faceplate thickness.**
- Optical and dimensional inspection and characterization of the finished mirror for overall optical figure accuracy and surface smoothness achieved by diamond turning.**

MIRROR MFG. PROCESS

Electroform NiP tubes with the required length and diameter and with one end closed and the other open.

Machine plastic foam to desired shape of substrate master. With press-fit holes for NiP tubes which go completely thru the foam master.

Install electroformed tubes in foam master so that the closed ends of the tubes are flush with the optical contour of the foam master.

Seal and coat plastic master with electrically conductive thin film to allow electroplating.

Electroplate the master and inserted tubes to completely encapsulate the assembly; joining the tubes to the front and back surfaces to form a stiff, continuous NiP structure.

Drill access holes through the NiP skin to allow introduction of solvent.

Use solvent such as acetone to dissolve the plastic master and leave only a mirror substrate of electroplated NiP alloy.

Diamond turn the exterior of the NiP mirror substrate to produce the desired optical contour and mounting and reference surfaces.

Optical inspection of the finished mirror.

Weight of 1 Sq. Meter Mirror

Polystyrene Foam Electroform Master

Backplate
0.040" Thk. x 50" dia.

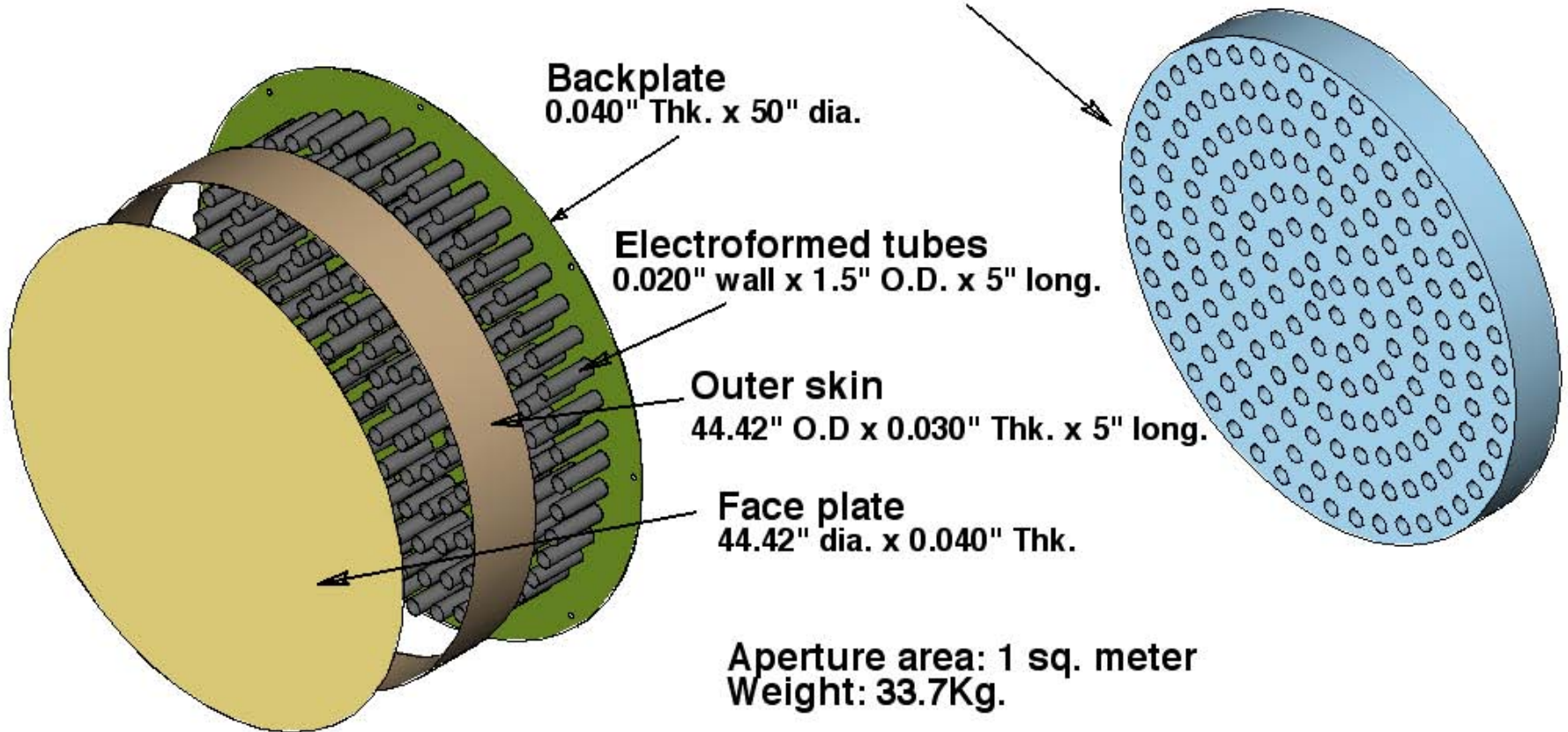
Electroformed tubes
0.020" wall x 1.5" O.D. x 5" long.

Outer skin
44.42" O.D x 0.030" Thk. x 5" long.

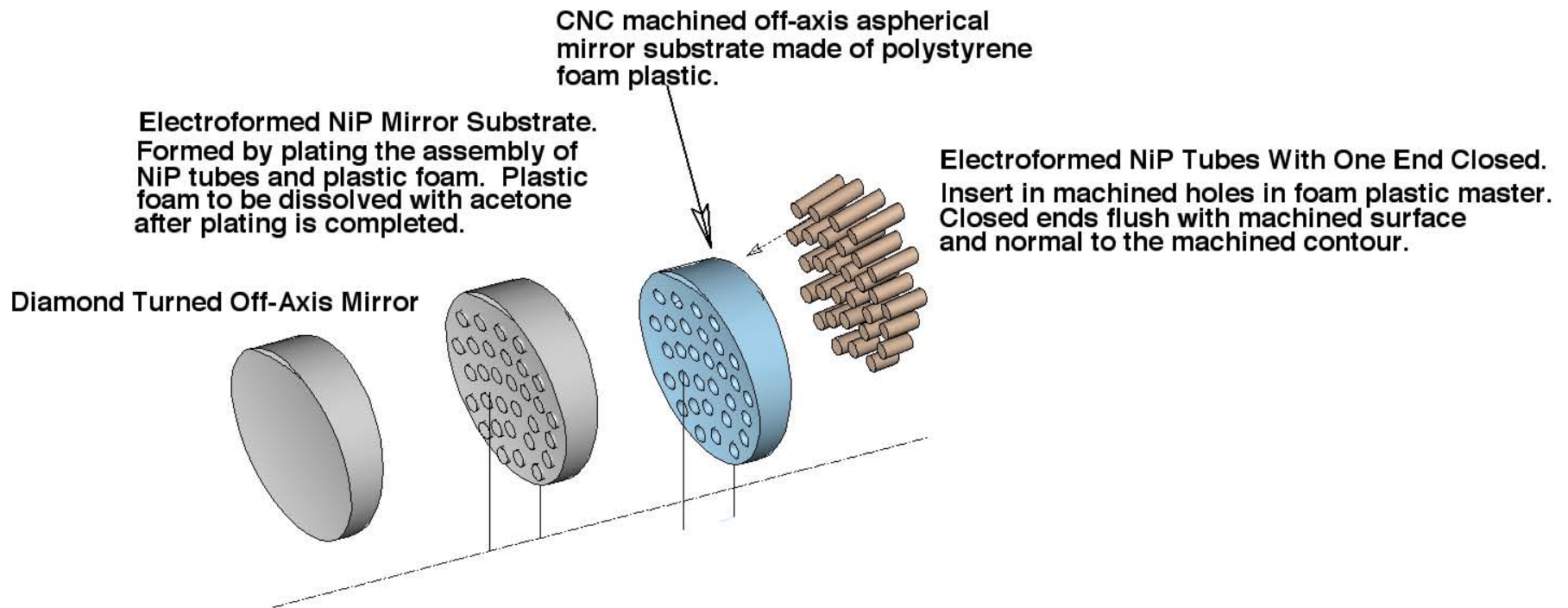
Face plate
44.42" dia. x 0.040" Thk.

Aperture area: 1 sq. meter
Weight: 33.7Kg.

After diamond turning mirror surface and back plate.
Weight: 27 Kg.



Off-Axis Aspheric Mirror



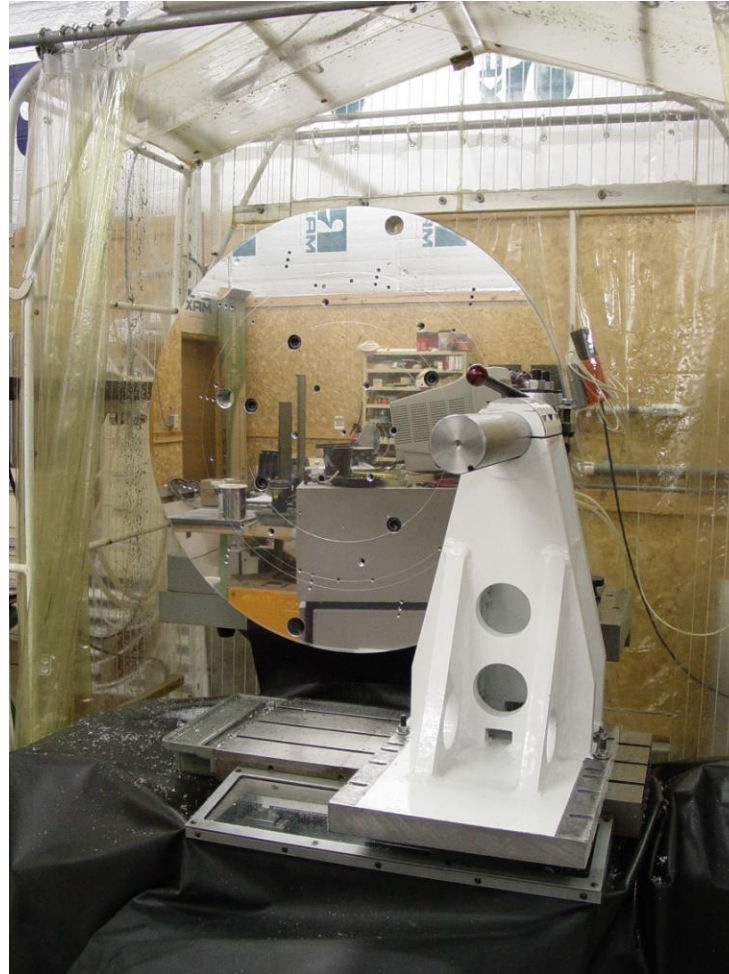
1.8 Meter Diameter Foam Plastic Mirror Substrate



2.48 Meter Aluminum Mirror



Large Part Diamond Turning Experience



Technology

- A very important enabling process for plating high phosphorus nickel alloys using an electrolytic process has been developed at the University of Alabama at Huntsville and at Marshall Space Flight Center. This plating process has been demonstrated to be capable of producing very low stress deposits of very high quality that allow excellent surfaces to be diamond turned on the NiP deposit. The electrolytic NiP plating process is not limited in plating thickness. Thick wall, structurally robust mirror substrates can be built up with this electroplating process.



Electrodeposited Nickel Phosphorus



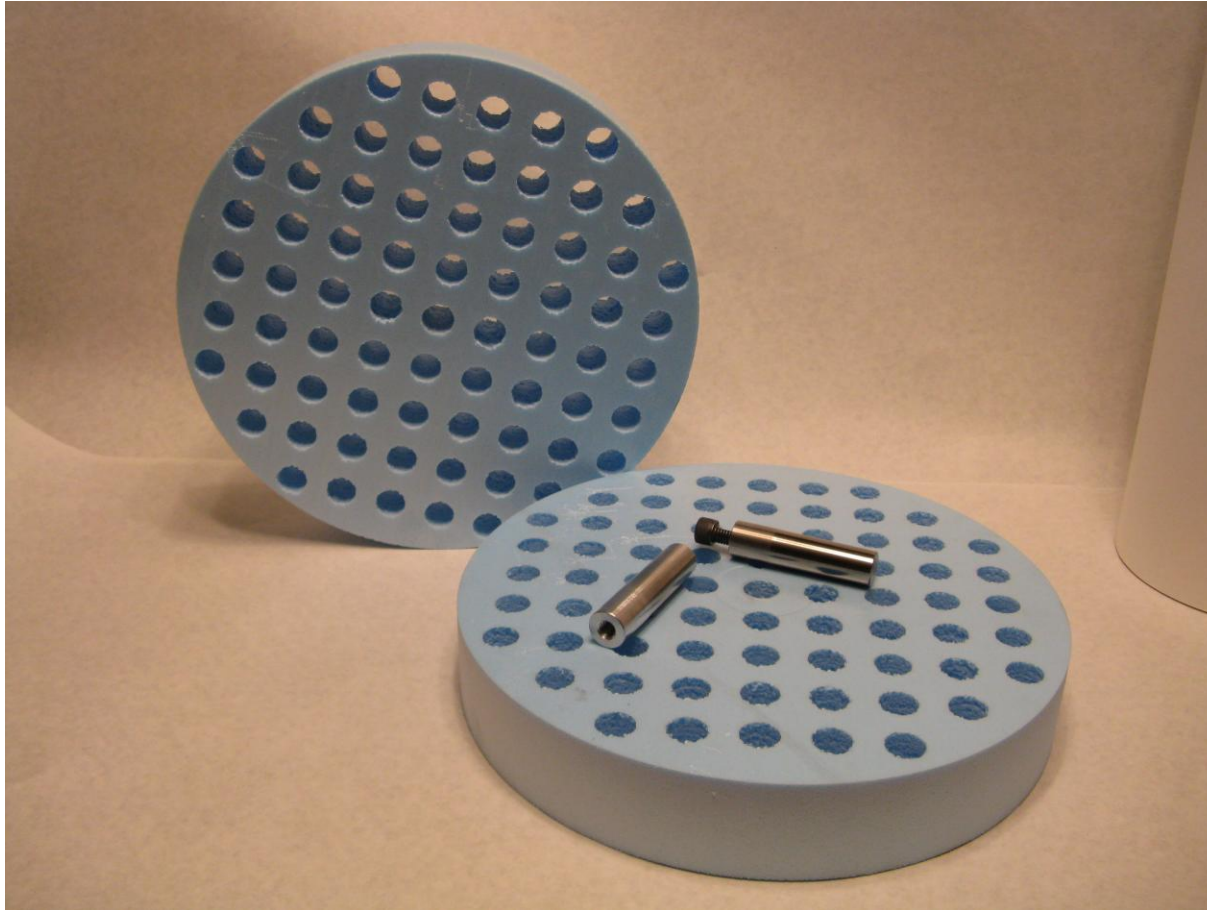
Comparison of Nickel Phosphorus Deposition to Other Processes

Parameter	Nickel	Electroless Nickel	NiP & NiCoP (Electrolytic)
Plating Temp °C	38 – 50	82 – 90	40 – 50
Control Method	Soluble Anode	Chemical Replenish	Soluble Anode
Yield (0.2%) (MPa)	500	See UTS	See UTS
MicroYield (MPa)	70	500 +	830 +
UTS Max (MPa)	800	850	1800 – 2150
Specific Gravity	8.9	7.8 – 8.0	7.8 – 8.0
Stress Control (Real Time)	Yes	No	Yes
Hardness (Rockwell C)	22 – 24	48 – 52	48 – 52
Diamond Machining	No	Yes	Yes
Thick Deposits	Yes	No	Yes

Electroforming Technology Developed by UAH and MSFC for X-Ray Telescope Fabrication

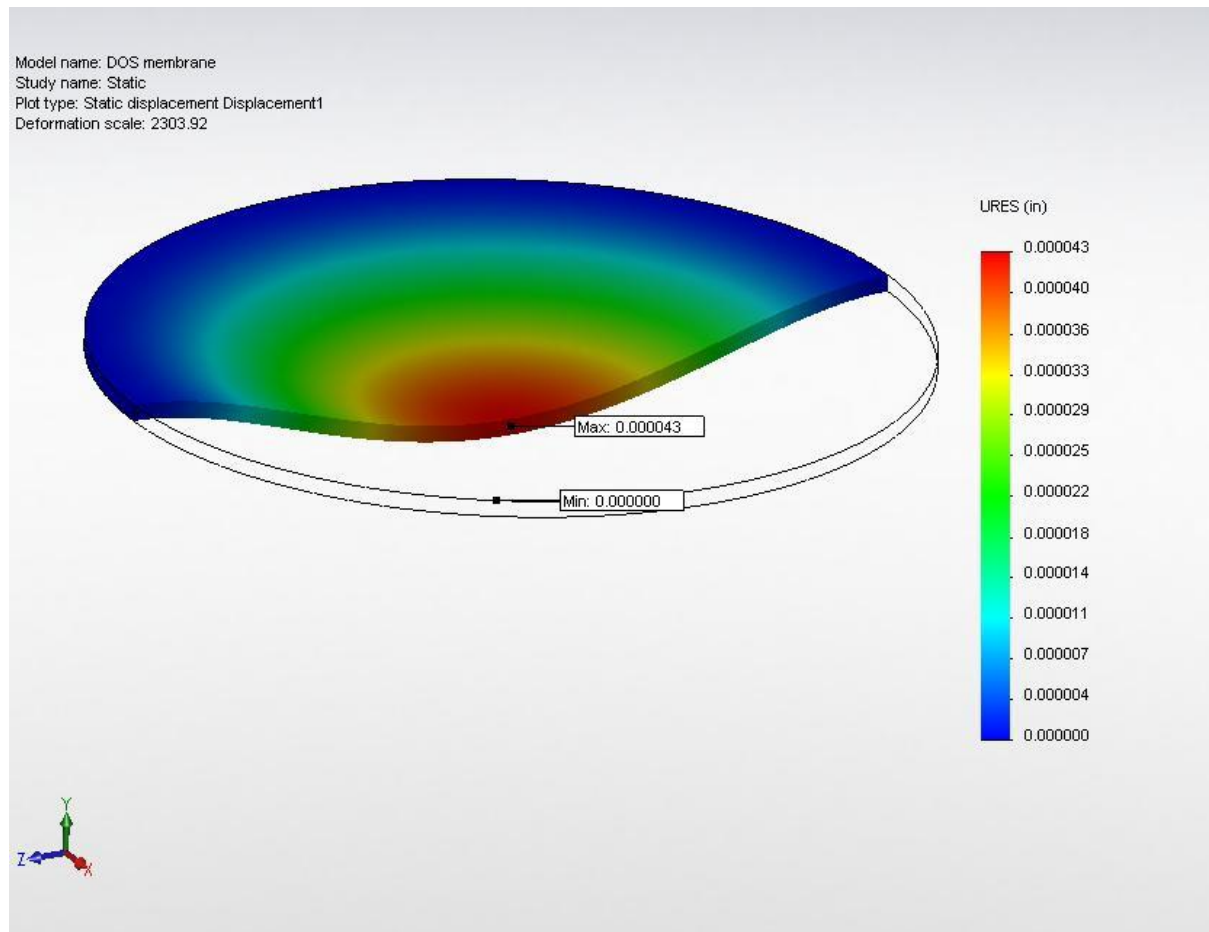


0.3 Meter PLASTIC FOAM MIRROR FORM

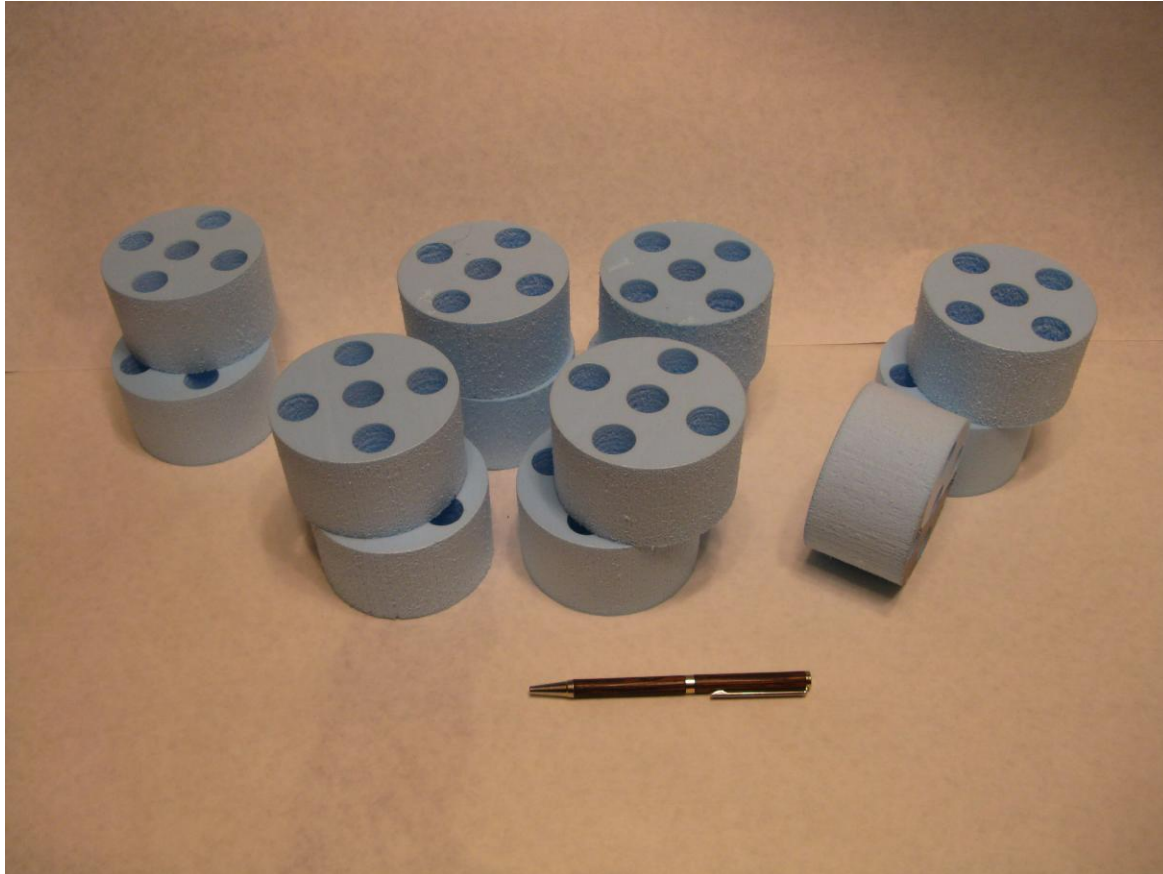


MIRROR DESIGN

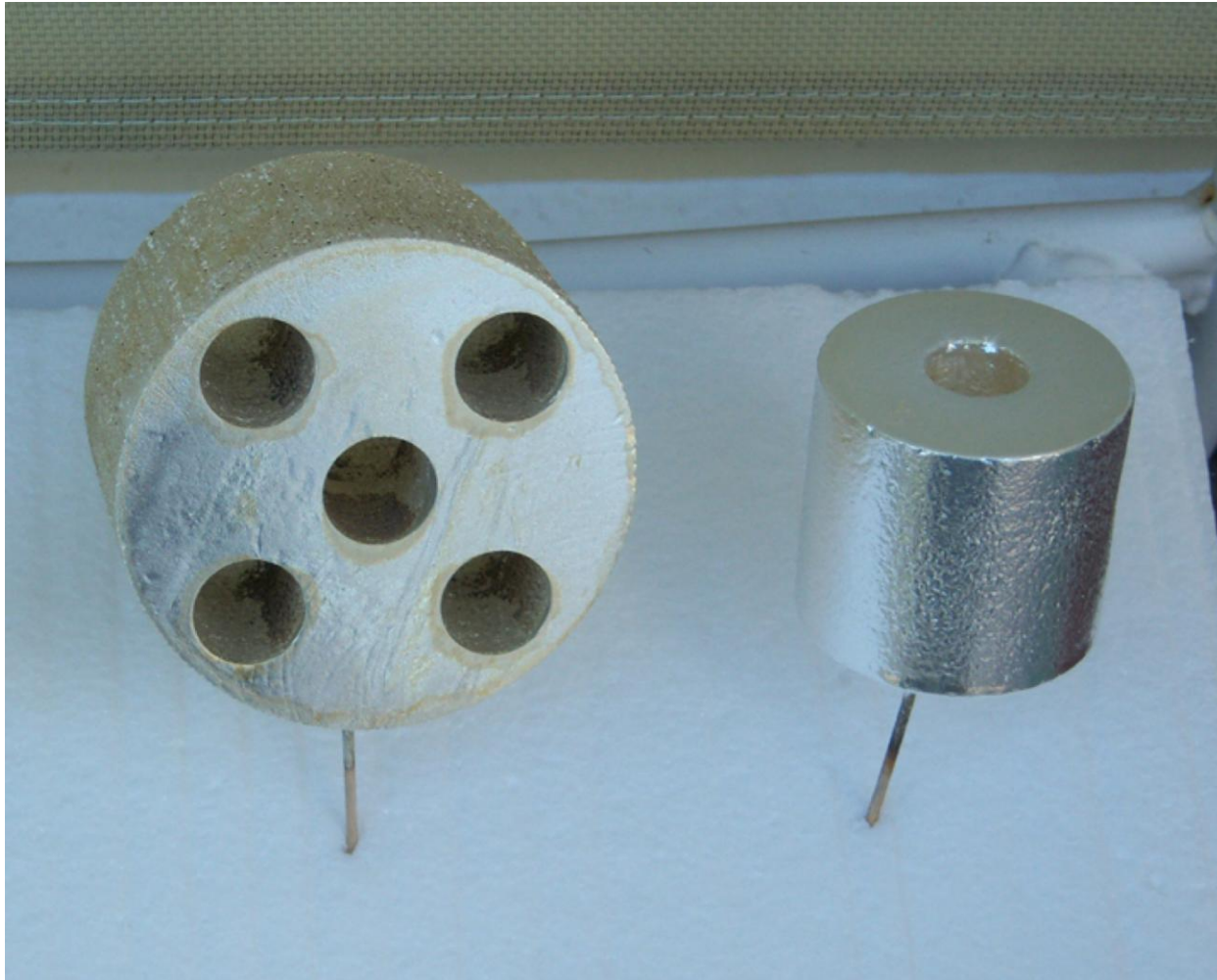
Plating thicknesses and diameter and spacing of tubes optimized for best performance.



89mm DIAMETER FOAM MASTER FORMS



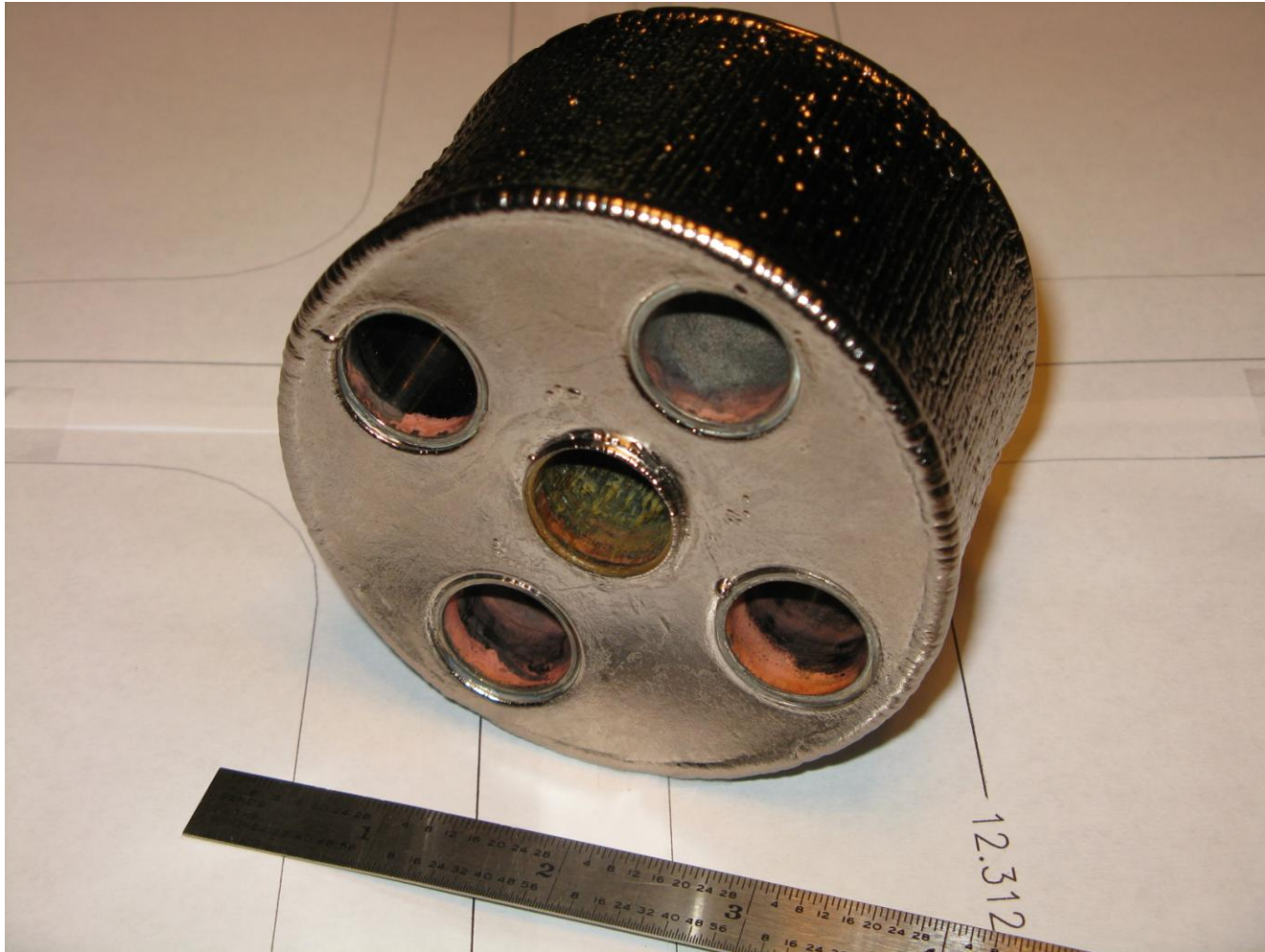
MIRROR FORM COATED WITH ELECTRICALLY CONDUCTIVE MATERIAL FOR PLATING



Electroformed NiP Tubes



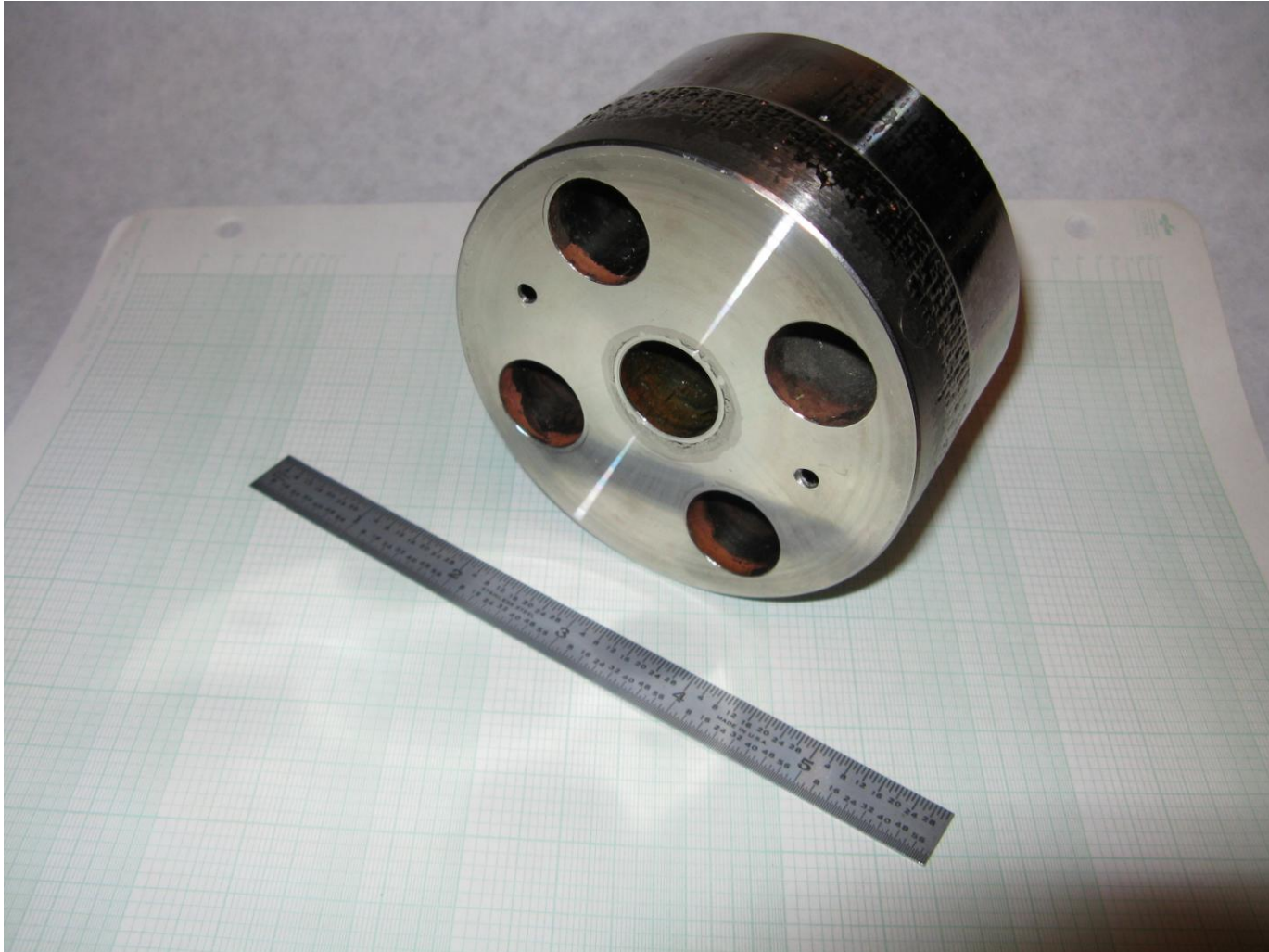
NiP Plated 89mm Mirror Substrate Assembly



Grinding Excess NiP Plating From Mirror Substrate



Precision Machined Back of Plated Mirror Assembly



Diamond Turned and Polished NiP Mirror



SUMMARY

- **Low Cost Mirror *SUBSTRATE* by Electroplating of NiP.**
- **Diamond Turning of NiP Electroformed Substrate.**
- **Low Cost Very Flexible Manf. Process for Large Mirrors.**
- **Low Areal Density, Very stiff metal mirror.**
- **Only one material means low thermal distortion.**